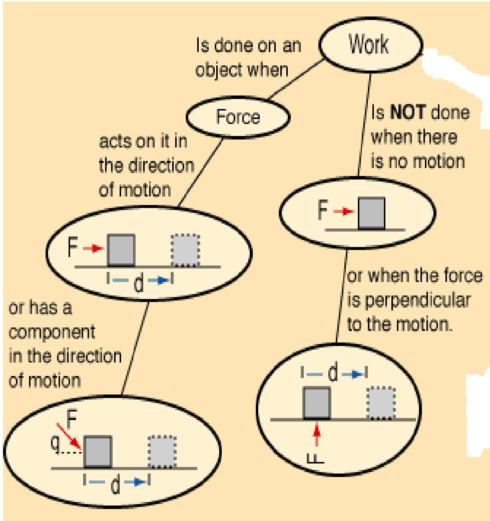
THIS CONCEPT IS BIG

Work / Energy / Power



Work- refers to an activity involving a force and movement in the directon of the force. A force of 20 newtons pushing an object 5 meters in the direction of the force does 100 joules of work.

When a force acts upon an object to cause a displacement of the object, it is said that **work** was done upon the object. **There are three key *ingredients* to work - force, displacement, and cause**.

In order for a force to qualify as having done work on an object, there must be a displacement and the force must cause the displacement.

There are several good examples of work which can be observed in everyday life - a horse pulling a plow through the field, a father pushing a grocery cart down the aisle of a grocery store, a freshman lifting a backpack full of books upon her shoulder, a weightlifter lifting a barbell above his head, an Olympian launching the shot-put, etc. In each case described here there is a force exerted upon an object to cause that object to be displaced.

Statement Answer with Explanation

A teacher applies a force to a wall and becomes exhausted. This is not an example of work. The wall is not displaced. A force must cause a displacement in order for work to be done.

A book falls off a table and free falls to the ground. This is an example of work. There is a force (gravity) which acts on the book which causes it to be displaced in a downward direction (i.e., "fall").

A waiter carries a tray full of meals above his head by one arm straight across the room at constant speed. (Careful! This is a very difficult question which will be discussed in more detail later.) This is not an example of work. There is a force (the waiter pushes up on the tray) and there is a displacement (the tray is moved horizontally across the room). Yet the force does not cause the displacement. To cause a displacement, there must be a component of force in the direction of the displacement.

The Joule is the unit of work.

1 Joule = 1 Newton x 1 meter

1 J = 1 N x m

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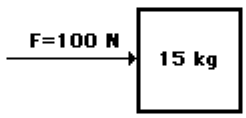
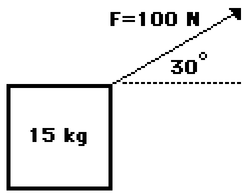
Problem Patterns





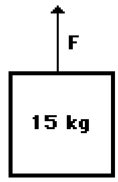


Diagram A	Diagram B	Diagram C
A 100 N force is applied to move a 15 kg object a horizontal distance of 5 meters at constant speed.	A 100 N force is applied at an angle of 30° to the horizontal to move a 15 kg object at a constant speed for a horizontal distance of 5 m.	An upward force is applied to lift a 15 kg object to a height of 5 meters at constant speed.

Diagram A Answer:

W = (100 N) * (5 m)* *cos(0 degrees)* = **500 J**

The force and the displacement are given in the problem statement. It is said (or shown or implied) that the force and the displacement are both rightward. Since F and d are in the same direction,the angle is 0 degrees.

Diagram B Answer:

W = (100 N) * (5 m) * cos(30 degrees) = **433 J**

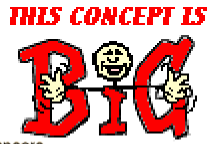
The force and the displacement are given in the problem statement. It is said that the displacement is rightward. It is shown that the force is 30 degrees above the horizontal. Thus, the angle between F and d is 30 degrees.

Diagram C Answer:

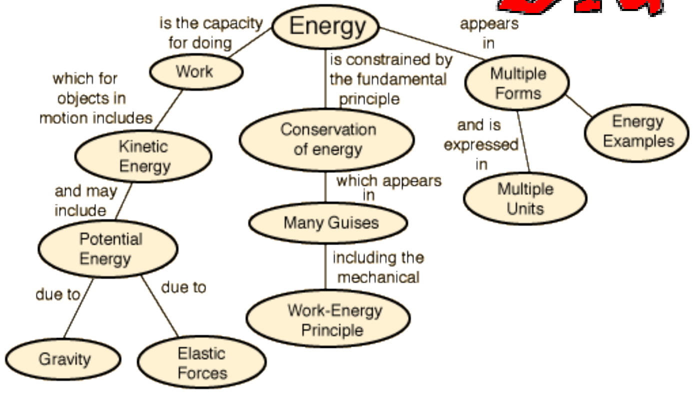
W = (147 N) * (5 m) * *cos(0 degrees)* = **735 J**

The displacement is given in the problem statement. The applied force must be 147 N since the 15-kg mass (F_{grav}=147 N) is lifted at constant speed. Since F and d are in the same direction, the angle is 0 degrees.

If the force is in the same plane not trigonometry is required – Concept VECTORS

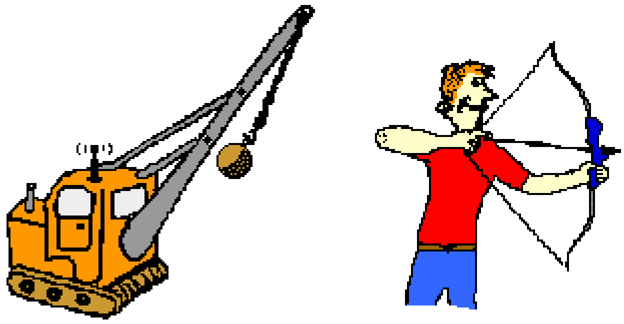


Energy- is the capacity for doing work. You must have energy to accomplish work - it is like the "currency" for performing work. To do 100 joules of work, you must expend 100 joules of energy.



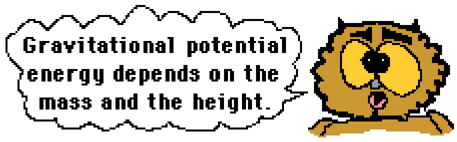
Potential Energy

An object can store energy as the result of its position. For example, the heavy heavy ball of a demolition machine is storing energy when it is held at an elevated position. This stored energy of position is referred to as potential energy. Similarly, a drawn bow is able to store energy as the result of its position. When assuming its *usual position* (i.e., when not drawn), there is no energy stored in the bow. Yet when its position is altered from its usual equilibrium position, the bow is able to store energy by virtue of its position. This stored energy of position is referred to as potential energy. **Potential energy** is the stored energy of position possessed by an object.



The massive ball of a demolition machine and the stretched bow possesses stored energy of position - potential energy.

Gravitational potential energy is the energy stored in an object as the result of its vertical position or height. The energy is stored as the result of the gravitational attraction of the Earth for the object. The gravitational potential energy of the massive ball of a demolition machine is dependent on two variables - the mass of the ball and the height to which it is raised



There is a direct relation between gravitational potential energy and the mass of an object. More massive objects have greater gravitational potential energy. There is also a direct relation between gravitational potential energy and the height of an object.

The higher that an object is elevated, the greater the gravitational potential energy.

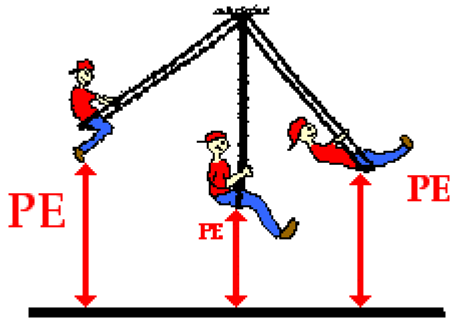
These relationships are expressed by the following equation:

$$PE_{grav} = mass * g * height$$

$$PE_{grav} = m * g * h$$

In the above equation, **m** represents the mass of the object, **h** represents the height of the object and **g** represents the acceleration of gravity (9.8 m/s/s on Earth).

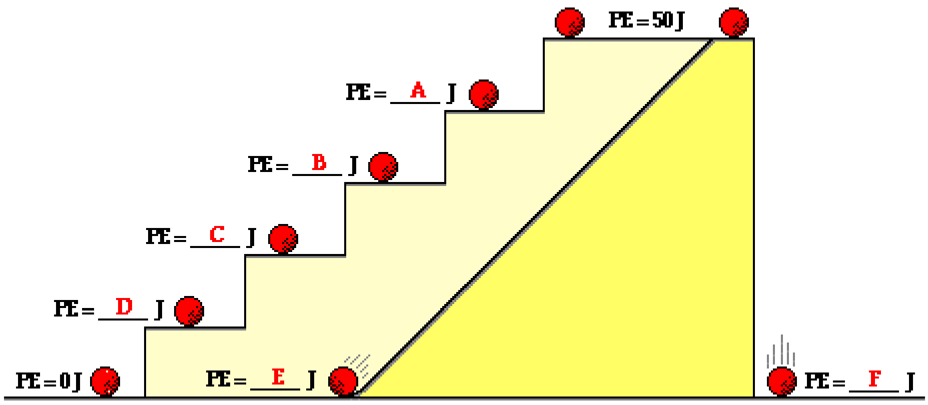
To determine the gravitational potential energy of an object, a zero height position must first be arbitrarily assigned.

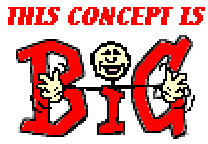


Typically, the ground is considered to be a position of zero height. But this is merely an arbitrarily assigned position which most people agree upon. Since many of our labs are done on tabletops, it is often customary to assign the tabletop to be the zero height position. Again this is merely arbitrary. If the tabletop is the zero position, then the potential energy of an object is based upon its height relative to the tabletop. For example, a pendulum bob swinging to and from above the table top has a potential energy which can be measured based on its height above the tabletop. By measuring the mass of the bob and the height of the bob above the tabletop, the potential energy of the bob can be determined.

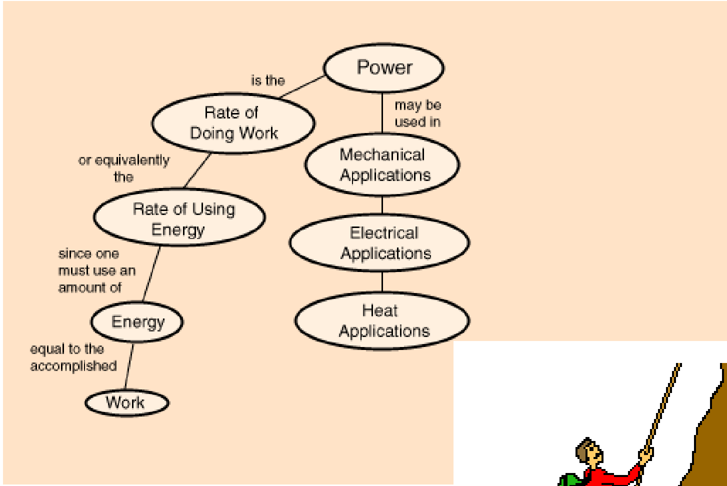
Since the gravitational potential energy of an object is directly proportional to its height above the zero position, a *doubling* of the height will result in a *doubling* of the gravitational potential energy. **A *tripling* of the height will result in a *tripling* of the gravitational potential energy.**

Use this principle to determine the blanks in the following diagram. Knowing that the potential energy at the top of the tall platform is 50 J, what is the potential energy at the other positions shown on the stair steps and the incline? Each Step is the same height

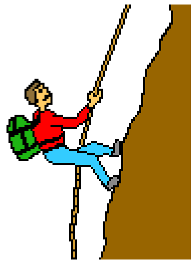




Power- is the rate of doing work or the rate of using energy, which are numerically the same. If you do 100 joules of work in one second (using 100 joules of energy), the power is 100 watts



The quantity work has to do with a force causing a displacement. Work has nothing to do with the amount of time that this force acts to cause the displacement. Sometimes, the work is done very quickly and other times the work is done rather slowly. For example, a rock climber takes an abnormally long time to elevate her body up a few meters along the side of a cliff. On the other hand, a trail hiker (who selects the easier path up the mountain) might elevate her body a few meters in a short amount of time. The two people might do the same amount of work, yet the hiker does the work in considerably less time than the rock climber. The quantity which has to do with the rate at which a certain amount of work is done is known as the power. The hiker has a greater *power rating* than the rock climber.

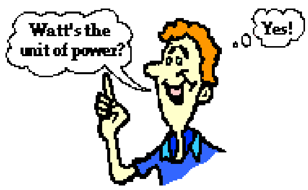


Rock climbers do a lot of work at a slow rate; their power is small.

Power is the rate at which work is done. It is the work/time ratio. Mathematically, it is computed using the following equation.

$$\text{Power} = \frac{\text{Work}}{\text{time}}$$

The standard metric unit of power is the **Watt**. As is implied by the equation for power, a unit of power is equivalent to a unit of work divided by a unit of time. Thus, a Watt is equivalent to a Joule/second.



Work-Energy Principle

$$W_{net} = \frac{1}{2} mv_{final}^2 - \frac{1}{2} mv_{initial}^2$$

(Vectors)

The change in the kinetic energy of an object is equal to the net work done on the object. This fact is referred to as the Work-Energy Principle and is often a very useful tool in mechanics problem solving. It is derivable from conservation of energy and the application of the relationships for work and energy, so it is not independent of the conservation laws. It is in fact a specific application of conservation of energy. However, there are so many mechanical problems which are solved efficiently by applying this principle that it merits separate attention as a working principle.

For a straight-line collision, the net work done is equal to the average force of impact times the distance travelled during the impact.
Average impact force x distance travelled = change in kinetic energy
If a moving object is stopped by a collision, extending the stopping distance will reduce the average impact force.